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Could different TMJ disc position observed in MRI cause different sounds? Analysis on a group of subjects with ADD with reduction: a pilot study

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AIMS

Magnetic Resonance Imaging (MRI) is the method of choice for examining soft-tissue pathology of the temporomandibular joint (TMJ). MRI shows a high spatial resolution with an accuracy for the identification of internal derangement. Tasaki developed a classification system for disc displacement in the TMJ, identifying eight different types of disc displacements in addition to the superior disc position.

This study aims to test the ability of Electrosonography (ESG) in discriminating different kinds of disc displacement according to the disc position criteria proposed, comparing the ESG results with those obtained by MRI.

METHODOLOGY

Twenty-seven patients were selected from an initial group of 50 patients with Articular Disc Displacement (ADD), selected by means of clinical examinations according to the RDC/TMD and who had both MRI and ESG studies performed. For each patient and for each peak in ESG, both in the opening and closing movement, three different parts of the sound were analyzed. The frequency (Hz) and the mean amplitude (μV) of the sounds were calculated in the three analyzed windows. Afterwards, gathering the data for the Tasaki's classes and dividing opening and closing sounds, the number of peaks was calculated, as well as average and standard deviations for both the Hz and μV.

RESULTS

The peak frequency shows significant differences between different disc position during the first and second third of the opening phase and during the first third of the closing phase.

The peak amplitude shows significant differences between different disc position during all the opening and closing phases.

CONCLUSIONS

Although limited by sample size, the present study shows the presence of different sounds with different Hz and μV associated with different disc positions that were recorded with ESG.

KEYWORDS: Magnetic Resonance Imaging, Electrosonography, Temporomandibular Joint, Articular Disc Displacement.

INTRODUCTION

The term temporomandibular disorders (TMD) is used to refer to a group of musculoskeletal and neuromuscular conditions that involve the temporomandibular joints (TMJs), the masticatory muscles, and all associated tissues.[1] In addition to complaints of pain, patients with these disorders frequently have a limited range of mandibular movement and TMJ sounds most frequently described as “clicking”, “popping”, “grating” or “crepitus”.[1] Some of these sounds are produced by a localized mechanical fault interfering with smooth joint movement, i.e., an internal derangement of the TMJ. The internal derangement of the TMJ is defined as “a deviation in position or form of the tissues within the capsule of the temporomandibular joint”.[2] Disc displacement is an example of internal derangement.

A recent systematic review reported a prevalence of up to 16% for disc derangement disorders in the general population.[3] Other studies show that TMDs are a condition of young and middle-aged adults rather than of children or the elderly, and are approximately twice as common in women than in men.[4-5] Manfredini[6] and Guarda Nardini reported that the most frequent Research Diagnostic Criteria for Temporomandibular Disorders (RDC/TMD) group II diagnosis was disc displacement with reduction, with a prevalence ranging from about 10% to 35%, while disc displacement without reduction with or without limited opening had a lower frequency (0% to 12%). In other studies, asymptomatic disc displacement was documented in approximately 30% of the population.[7-9] On the other hand, 82% of patients presenting with pain and functional disturbance of their TMJ will have displaced discs, when examined with Magnetic Resonance Imaging (MRI).[9]

Clicking sounds are clinically observed at the moment of disc reduction and/or dislocation during a mouth opening/closing movement. Studies evaluating the diagnostic agreement between patient's clicking sounds and findings from Magnetic Resonance Imaging (MRI) yielded Kappa value which greatly varied between 0.038 (poor agreement) and 0.678 (substantial agreement).[10-12] Accepting MRI as the gold standard would indicate that a reducible disc displacement cannot be diagnosed unequivocally by the clinical clicking test.[13]

MRI is the method of choice for examining soft-tissue pathology of the TMJ. MRI shows a high spatial resolution with an accuracy of 85-100% for the identification of internal derangement or degenerative osseous changes with flattening, sclerosis, erosion and osteophyte formation of the TMJ.[14] Tasaki et al.[15] reported a 95% accuracy in the assessment of disc position and configuration, and 93% accuracy in the assessment of osseous changes of the TMJ.

MRI cannot be carried out in some patients (those with pacemakers, claustrophobics), and its use is limited by the cost and the time it takes.[6] The need has arisen for alternative techniques that have good diagnostic accuracy and reliability. Electrosonography (ESG) may be a useful method in the assessment of the disc position in suspected cases of internal derangement.[13,14]

In a previous paper[16] the authors demonstrated that the presence of a peak-shaped track in ESG has high specificity for Articular Disc Displacement with Reduction (ADDwR) (90.27%). The use of ESG to support the clinical diagnosis of a disc displacement with reduction was thus recommended when MRI is not available or when subjects cannot be analyzed by MRI.

Tasaki[17] developed a classification system for disc displacement in the TMJ. The study was based on bilateral MRIs of 243 patients and 57 symptom-free volunteers. Eight different types of disc displacements were identified, in addition to the superior disc position and a tenth indeterminate category.

The aim of this study was to test the ESG ability in discriminating different kinds of disc displacement according to the disc position criteria proposed by Tasaki, comparing the ESG results with those obtained by MRI. The hypothesis is that ESG could substitute for MRI in identifying disc displacements when MRI is not available or when subjects cannot be analyzed by MRI.

MATERIALS AND METHODS

Subjects

Twenty-seven patients (9 males and 18 females; age range 17 - 65 years old; mean age = 33.3 ± 13.65 years old) were selected from an initial group of 50 patients with Articular Disc Displacement with or without reduction, selected by means of clinical examinations according to the RDC/TMD[18] and who were analyzed with MRI and ESG (ESG-2 device, Myotronics Inc., Kent, WA, USA). As inclusion criteria, patients were required to have a peak ESG aspect in one or both TMJs upon mouth opening and/or closing and ADDwR diagnosis with MRI.

Out of the 27 patients included in the study, 18 presented an ESG peak in only one TMJ and 9 patients in both TMJs. The total of TMJs examined was 36.

The initial group was selected among all the orofacial pain patients who visited the Gnathology Unit of the Dental School of the University of Torino (Italy), in the period of

March through December 2011. The selected subjects gave informed written consent for the study, which was approved by the human investigation committee at the authors' institution.

Magnetic Resonance

The MRI study was conducted in intercuspal position and at the maximum opening, in order to investigate the disc position and the eventual reduction during mouth opening.

The MRI was carried out with a 1.5 Tesla (Gyroscan, Philips) with a bilateral dedicated circular (8-cm diameter) surface coil for concomitant right and left TMJ study.

The MRI of each subject was completed and interpreted by radiologists, who were blinded to the clinical examination findings and to the research. The investigation protocol provided a first axial scan ''scout'' from which were established seven sagittal-oblique slices in a lateral-medial direction and coronal sections deviated obliquely in a postero-anterior direction. Gradient Echo sequences were performed: 2D T1-weighted in sagittal-oblique sections at closed and open mouth and coronal sections at closed mouth (TR = 340 ms, TE = 16 ms, field of view = 15 cm, slice thickness = 3 mm, matrix 256 x 192) with an interslice gap of 0.5 mm. Sequential bilateral images in both closed mouth and maximum opening mouth positions were made (fig 1A and 1B). The articular disc was directly identified, in sagittal-oblique images, as an area of hypointensity with a biconcave shape above the condylar structure, and its position was categorized according to literature data.[11] Bone contours, cartilage integrity, bone marrow abnormalities, disc shape and structure and joint effusion were evaluated. The diagnostic accuracy of MRI on fresh autopsy material using oblique sagittal and oblique coronal sections has been found to be 95 and 93%, respectively, in determining the disc position and the bone status.[19]

The disc position criteria proposed by Tasaki[17] were used to classify the MRI analysis of the analyzed TMJs. The MRIs of all the patients were classified by an expert operator looking at both lateral-medial sections (sagittal) and coronal sections (see Tab 1).

Electrosonography

Using the ESG-2 device (Myotronics Inc., Kent, WA, USA) connected to a K-7 system (Myotronics Inc., Kent, WA, USA), TMJ patients' vibrations were evaluated. The authors checked the absence of interference between the two systems by measuring opening and closing movements with and without the transducers in place. If the recorded movements didn't change, no interference was present.

The ESG-2 is a lightweight headset that holds highly sensitive microphones over each TMJ, enabling simultaneous, bilateral capture of tissue vibrations emanating from joint sounds. It includes an amplifier to transfer and record the collected data. Vibration (sound) data is correlated to vertical dimension of opening and closing provided by the jaw tracking device (K-7 system, Myotronics Inc., Kent, WA, USA), used simultaneously with the ESG-2. The frequency response of the electrosonographic device is between 15 and 720 Hz with a special filter that reject 50 Hz frequency.

The skin over the lateral TMJ pole was slightly abraded (Every Paste, Meditec, Parma, Italy) before the analysis began. After positioning the sensors, the patients were asked to open and close the mouth accompanying an arrow motion on the monitor screen. All patients were allowed one minute of training to synchronize the movement with arrow motion. After confirming synchronism, the records were accepted and saved on a hard disc for further analysis. The analysis was performed by an operator blinded to the clinical and MRI diagnosis.

Each record consisted of four movements, which were repeated three times for a total of 12 movements.

The recorded vibrations were displayed as tracking on a monitor (Fig. 2).

The twelve opening/closing movements were examined searching for a sound peak. If the peak was present in at least seven out of twelve moves, the patient was considered positive for the presence of peak and included in this study.

The software (K-7 system, Myotronics Inc., Kent, WA, USA) can automatically perform and display a spectral analysis of a part (working range) of the vibration, in order to visualize the frequency distribution (Hz) and the mean amplitude (μV) in that part of the sound. This working range can be of 50 or 100 ms. (Fig.3).

For every patient and for every peak, both in the opening and closing movement, three different parts of the sound were analyzed using a working range of 50 mSec: the ascending part (window 1), the central part where the sound is higher (window 2) and the descending part (window 3). In the three analyzed windows, frequency (Hz) and the mean amplitude (μV) of the sound were calculated and reported in a table as well as the disc position according to Tasaki.[17] After compiling the data for the Tasaki's classes and dividing opening and closing sounds, the number of peaks was calculated, as well as average and Standard deviation for both the Hz (Tab 2 and Fig 4, 5) and μV (Tab 3 and Fig 6, 7) for the three windows.

The ANOVA Univariate test was used to detect the statistical differences between the different disc positions with significant differences for $p<0.05$ (Tab 4, 5).

RESULTS

The distribution of the different disc positions of the 36 investigated TMJs, according to Tasaki[17] is reported in Table 1.

Not all the movements presented a peak aspect, so the total number of movements presenting this characteristic was 257 during the opening and 228 during the closing phase.

Regarding the ESG sound aspect of a peak morphology, the mean frequency (Hz), the mean amplitude (μV) and their relationships with the opening phase, the closing phase and the disc position were reported in Table 2 and 3 and in figures 4 to 7. The ANOVA test results (Tables 4 and 5) showed that the peak frequencies of the first third of the opening phase were significantly greater for the disc position 3 (anterior disc displacement at the lateral portion of the TMJ) than those observed for the disc position 2 (anterior disc displacement) and the disc position 6 (antero-medial disc rotation) (p=0.001). During the second third of the opening phase, the frequencies of the disc position 3 were greater than those of the disc position 2 and 5 (antero-lateral disc rotation) (p=0.006). During the last third of the opening phase the observed differences were not significant.

During the first third of the closing phase the peak frequencies observed for the disc position 7 (disc in lateral position) were significantly greater than those observed for the disc position 2,3, and 4 (partial anterior disc displacement in the medial aspect of the TMJ) and 6 (p=0.0001). During the second and the last third of the closing phase the observed differences were not significant.

The ANOVA test results showed a greater peak amplitude during all the opening phases for the disc position 4 (p=0.0001), while for the disc position 7, lower values than those observed for the disc positions 2,3 and 4 were reported.

During the first third of the closing phase the peak amplitude of the disc position 4 was significantly lower than that observed for the disc positions 2 and 6 (p=0.0001), while during the second third it was significantly lower than that observed for the disc positions 2 and 3 (p=0.0001). During the last third of the closing phase the peak amplitude of the disc position 4 was significantly lower than that observed for the disc position 2 (p=0.003).

DISCUSSION

The importance of MRI in the diagnosis of TMDs has been confirmed in numerous studies. The articular disc displacement is one of the most common expressions of TMD, and MRI has excellent reliability for assessing disc position.[20] This characteristic was confirmed by studies in which a comparison between MRI and autopsy specimens revealed an accuracy of about 90–95% for detecting disc position abnormalities when both coronal and sagittal images are evaluated. The most salient sign of a disc displacement with reduction is a repeatable, audible click. On occasion the click is not audible but may be heard by auscultation. In addition, the shift in disc position may be felt by palpation.

In a previous study,[16] it was possible to show a good agreement between the MRI diagnosis of disc displacement with reduction and the ESG peak morphology with a Cohen's kappa coefficient of 0.56. Furthermore, a specificity of 90.24% and a PPV of 90% of the ESG peak morphology with respect to the MRI diagnosis of disc displacement with reduction, indicate 1) rare false positive cases and 2) the presence of this morphology is related to a diagnosis of ADDwR in 90% of the observed cases.

Considering the fact that MRI cannot be performed in all cases, and its use is limited by its cost and the time it takes, the ESG can be considered a good alternative technique as a support in the clinical diagnosis of ADDwR.

Tasaki[17] observed different types of disc displacement unilaterally or bilaterally both in TMD patients and in symptom-free volunteers. He observed a spectrum of disc displacements in all directions with anterolateral and anterior displacement being the most common, and he described nine different (plus one not classifiable) positions. In some of these positions the disc is not completely slipped out of its regular position, and parts of the condyle stay on the disc. These different positions, and different relationship between condyle and disc suggest the possibility of different sounds when the disc is recaptured.

In this study, the ESG results were analyzed dividing every sound related to an ADDwR in three thirds, and performing the spectral analysis of the sounds.

This analysis showed a progressive reduction of the frequency values passing from the first to the last third for both the opening and the closing phases. The mean values are included between 229Hz and 62Hz during the opening, and between 193Hz and 59Hz during the closing phases, in line with those reported by Hutta et al.,[21] who described a mean frequency of 112 Hz for the click sounds related to a disc displacement with reduction.

Regarding the amplitude recorded during the opening and the closing phases, the mean value is 1405μV during the second third of the opening, and 1272 μV during the second third of the closing phases. To the authors' knowledge, there are no similar results in literature: the few works in which this parameter was measured showed a lack of general consensus on the proper measurement unit.[22,23]

The spectral analysis of the peak frequencies of the different disc positions revealed greater mean values for the disc position 3 (318.75±252.01Hz) during the opening phase, while the amplitude analysis showed greater mean values for the disc position 4 (2330.37±747.12) during the opening phase, and lower mean values for the same disc position during the closing phase (410.33±251.6). Thus, on the basis of the ESG evaluation and of the relative spectral and amplitude analysis, it is possible to confirm with good precision an anterior disc displacement at the lateral portion of the TMJ (disc position 3) or an anterior disc displacement at the medial portion of the TMJ (disc position 4). However the considerations related to the disc position 4 have to be managed with caution since the relative sample was of only five TMJs.

To the authors' knowledge, this is the first study in which similar results were described. However, the sample in the present study was too small for several disc positions (4,5,7); the distribution of TMJ disc displacements according to Tasaki classification is in line with the distribution described in previous works on the role of MRI in the diagnosis of TMDs,[24] supporting the fact that the above mentioned disc positions with few subjects are probably rare.

In conclusion, although limited by sample size, the present study shows the presence of different sounds associated with different disc positions. Furthermore, the use of ESG in supporting the clinical diagnosis of a disc displacement with reduction is recommended when MRI is not available or when the subject cannot be analyzed by MRI. The spectral analysis and the amplitude analysis of the peak morphology can identify the disc position with good precision. However, further longitudinal studies are needed to confirm or to refute this hypothesis.

REFERENCES

1) De Leeuw R, Klasser GD. Orofacial pain. Guidelines for assessment, diagnosis and management. Fifth edition, Quintessence Pub, 2013:129-130.

2) The Glossary of Prosthodontic Terms. *J Prosthet Dent*. 2005;94:10-92.

3) Manfredini D, Guarda Nardini L, Winocur E, Piccotti F, Ahlberg J, Lobbezoo F. Research diagnostic criteria for temporomandibular disorders: a systematic review of axis I epidemiologic findings. Oral Surg Oral Med Oral Pathol Oral Radiol Endod. 2011;112:453-462.

4) LeResche L. Epidemiologyy of temporomandibular disorders: implications for the investigation of etiologic factors. Crit Rev Oral Biol Med. 1997;8:291-305.

5) Anastassaki Kohler A, Hugoson A, Magnusson T. Prevalence of symptoms indicative of temporomandibular disorders in adults: cross-sectional epidemiological investigation covering two decades. Acta Odontol Scand. 2012;70:213-223.

6) Manfredini D, Guarda-Nardini L. Ultrasonography of the temporomandibular joint: a literature review. *Int J Oral Maxillofac Surg*. 2009;38:1229-36.

7) Kircos LT, Ortendhal DA, Mark AS, Arakawa M. Magnetic resonance imaging of the TMJ disc in asymptomatic volunteers. J Oral Maxillofac Surg. 1987;45:852-854.

8) Larheim TA, Westesson P, Sano T. Temporomandibular joint disc displacement: comparison in asymptomatic volunteers and patients. Radiology 2001;218:428-432.

9) Limchaichana N, Petersson A, Rohlin M. The efficacy of magnetic resonance imaging in the diagnosis of degenerative and inflammatory temporomandibular joint disorders: a systematic literature review. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod*. 2006;102:521-36.

10) Emshoff R, Jank S, Bertram S, Rudisch A, Bodner G. Disc displacement of the temporomandibular joint: sonography versus MR imaging. *Am J Roentgenol*. 2002;178:1557-62.

11) Manfredini D, Guarda-Nardini L. Agreement between Research Diagnostic Criteria for Temporomandibular Disorders and magnetic resonance diagnoses of temporomandibular disc displacement in a patient population. *Int J Oral Maxillofac Surg*. 2008;37:612-6.

12) Yatani H, Sonoyama W, Kuboki T, Matsuka Y, Orsini MG, Yamashita A. The validity of clinical examination for diagnosing anterior disc displacement with reduction. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod*. 1998;85:647-53.

13) Naeije M, Te Veldhuis AH, Te Veldhuis EC, Visscher CM, Lobbezoo F. Disc displacement within the human temporomandibular joint: a systematic review of a 'noisy annoyance'. *J Oral Rehabil*. 2013;40:139-58.

14) Hansson LG, Westesson PL, Katzberg RW, Tallents RH, Kurita K, Holtås S, Svensson SA, Eriksson L, Johansen CC. MR imaging of the temporomandibular joint: comparison of images of autopsy specimens made at 0.3 T and 1.5 T with anatomic cryosections. *Am J Roentgenol*. 1989;152:1241-4.

15) Tasaki MM, Westesson PL, Raubertas RF. Observer variation in interpretation of magnetic resonance images of the temporomandibular joint. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod*. 1993;76:231-4

16) Deregibus A, Castroflorio T, De Giorgi I, Burzio C, Debernardi C. Diagnostic concordance between MRI and electrovibratography of the temporomandibular joint of subjects with disc displacement disorders. *Dentomaxillofac Radiol*. 2013;42:20120155.

17) Tasaki MM, Westesson PL, Isberg AM, Ren YF, Tallents RH. Classification and prevalence of temporomandibular joint disc displacement in patients and symptom-free volunteers. *Am J Orthod Dentofacial Orthop*. 1996;109:249-62.

18) Dworkin SF, LeResche L. Research diagnostic criteria for temporomandibular disorders: review, criteria, examinations and specifications, critique. *J Craniomandib Disord*. 1992;6:301-55.

19) Tasaki MM, Westesson PL. Temporomandibular joint: diagnostic accuracy with sagittal and coronal MR imaging. Radiology. 1993;186:723-9.

20) Ahmad M, Hollender L, Anderson Q, Kartha K, Ohrbach RK, Truelove EL, John MT, Schiffman EL. Research Diagnostic Criteria for Temporomandibular Disorders (RDC/TMD): Development of Image Analysis Criteria and Examiner Reliability for Image Analysis. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod*. 2009;107:844–860.

21) Hutta JL, Morris TW, Katzberg RW, Tallents RH, Espeland MA. Separation of internal derangements of the temporomandibular joint using sound analysis. *Oral Surg Oral Med Oral Pathol*. 1987;63:151-7.

22) Gay T, Bertolami CN. The spectral properties of temporomandibular joint sounds. *J Dent Res*. 1987;66:1189-94.

23) Wabeke KB, Spruijt RJ, van der Zaag J. The reliability of clinical methods for recording temporomandibular joint sounds. *J Dent Res*. 1994;73:1157-62.

24) Larheim TA. Role of magnetic resonance imaging in the clinical diagnosis of the temporomandibular joint. *Cells Tissues Organs*. 2005;180:6-21.

Position	Description	Joints	%
1	Superior disc position	0	0
2	Anterior disc displacement	14	38.9
3	Partial anterior disc displacement in lateral part	10	27.8
4	Partial anterior disc displacement in medial part	3	8.3
5	Rotational antero-lateral disc displacement	2	5.5
6	Rotational antero-medial disc displacement	6	16.7
7	Lateral disc displacement	1	2.8
8	Medial disc displacement	0	0
9	Posterior disc displacement	0	0
10	Intermediate	0	0

Tab. 1: Different disc positions found in current study according to Tasaki classification.

		Opening				Closing		
T	n	1	2	3	n	1	2	3
2	90	187.91±171.82	93.94±93.60	58.81±64.80	94	194.70±213.76	71.36±80.67	61.46±82.31
3	65	318.75±252.01	170.58±186.77	72.77±74.23	78	179.50±164.83	109.71±99.11	66.36±32.10
4	35	263.71±215.00	114.91±103.56	61.00±7.46	18	93.00±24.20	84.56±27.89	42.83±12.78
5	18	163.00±171.84	65.22±36.39	43.94±15.58	0	0	0	0
6	37	190.28±215.55	122.57±162.47	61.86±27.18	26	193.52±206.39	119.31±159.56	46.92±18.29
7	12	168.42±156.55	96.33±17.10	58.83±13.24	12	435.17±242.02	103.25±177.63	41.17±6.35
Tot	257	229.16±212.87	118.40±134.65	62.04±55.04	228	193.99±198.69	92.67±103.78	58.94±57.02

Tab 2: Average ± SD of the frequency (Hz) of the sound of the first (1), second (2) and last (3) third of the ESG's peaks. Data are divided in opening and closing peaks.

T=Tasaki's classes

n=number of peaks

		Opening				Closing		
T	n	1	2	3	n	1	2	3
2	90	1190.96±787.32	1366.84±917.21	845.09±652.50	94	1271.57±865.84	1506.51±983.11	961.67±675.69
3	65	1265.29±932.39	1419.94±1080.40	858.20±792.68	78	965.76±810.93	1137.05±969.57	788.33±761.52
4	35	2330.37±747.12	2735.03±943.47	1870.66±932.01	18	410.33±251.60	458.28±284.63	295.50±221.61
5	18	755.28±669.63	810.56±664.60	396.78±263.79	0	0	0	0
6	37	859.25±784.66	904.41±832.48	638.76±671.10	26	1218.52±836.65	1388.08±826.33	849.62±658.83
7	12	165.75±48.14	176.42±51.80	109.25±47.00	12	1178.00±118.68	1289.75±199.95	609.42±247.79
Tot	257	1240.27±937.56	1405.48±1097.11	892.61±822.45	228	1088.55±819.03	1272.45±938.69	818.46±686.39

Tab 3: Average ± SD of the intensity (µV) of the sound of the first (1), second (2) and last (3) third of the ESG's peaks. Data are divided in opening and closing peaks.

T=Tasaki's classes

n=number of peaks

	Opening			Closing		
	f	*p*	Sig	f	*p*	Sig
Window 1	4.194	0.001	2<3 (**), 3>6 (*)	6.206	0.000	2<7 (***), 3<7 (***), 4<7 (***), 6<7 (**)
Window 2	3.329	0.006	2<3 (**), 3>5 (*)	2.040	0.090	N.S.
Window 3	0.955	0.446	N.S.	1.323	0.262	N.S.

Tab 4: ANOVA test of the frequency (Hz) of the sound of the ESG's peaks divided in three windows (wondow 1, window 2, window 3). Analysis is divided in opening and closing peaks. Numbers in the Sig columns are the Tasaki's classes (*= p<.05, **=p<.01, ***=p<.001).

f= frequency

p= probability

Sig= significance

	Opening			Closing		
	f	*p*	Sig	f	*p*	Sig
Window 1	20.495	0.000	2>7 (***), 3>7 (***), 4>2 (***), 4>3 (***), 4>5 (***), 4>6 (***), 4>7 (***)	5.271	0.000	4<2 (***), 4<6 (**)
Window 2	22.651	0.000	2>7 (***), 3>7 (***), 4>2 (***), 4>3 (***), 4>5 (***), 4>6 (***), 4>7 (***)	5.805	0.000	4<2 (***), 4<3 (*), 4<6 (**),
Window 3	19.241	0.000	2>7 (*), 3>7 (*), 4>2 (***), 4>3 (***), 4>5 (***), 4>6 (***), 4>7 (***)	4.187	0.003	4<2 (***)

Tab 5: ANOVA test of the intensity (µV) of the sound of the ESG's peaks divided in three windows (window 1, window 2, window 3). Analysis is divided in opening and closing peaks. Numbers in the Sig columns are the Tasaki's classes (*= p<.05, **=p<.01, ***=p<.001).

f= frequency

p= probability

Sig= significance

Fig 1A

Fig 1B

Fig 1A: Sagittal slices of a TMJ with ADDwR using MRI. Mouth closed.

Fig 1B: Sagittal slices of a TMJ with ADDwR using MRI. Mouth opened. It is possible to observe the recapture of the disc.

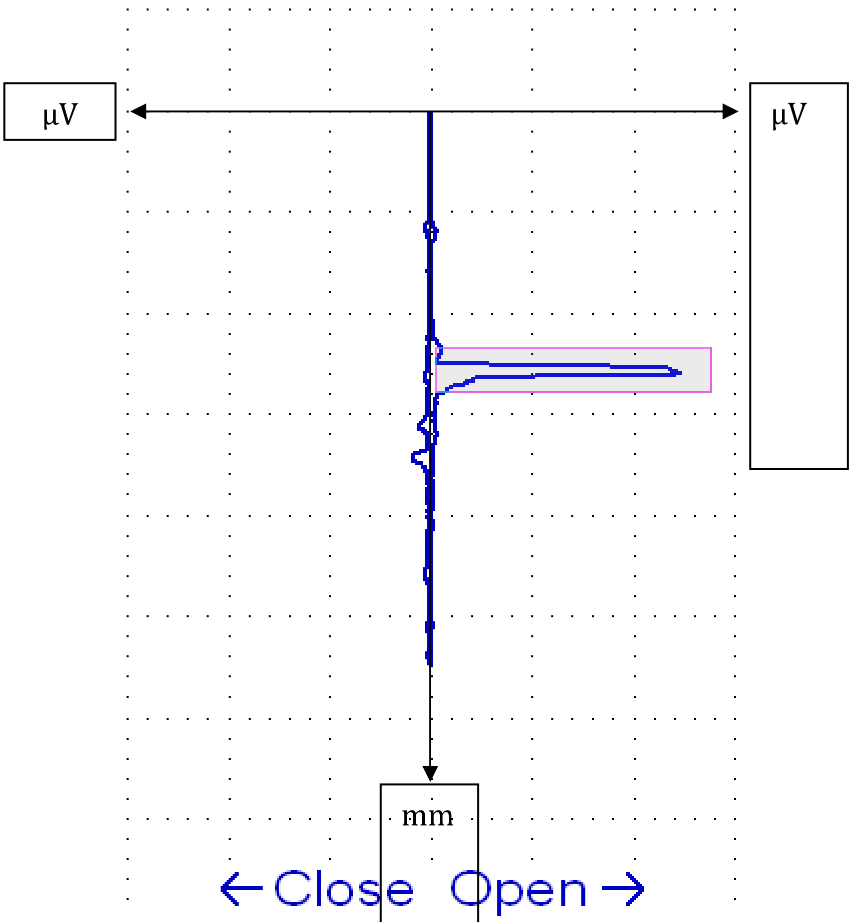

Fig. 2: Typical example of peak morphology in Electrosonography observed during the opening and closing movements.

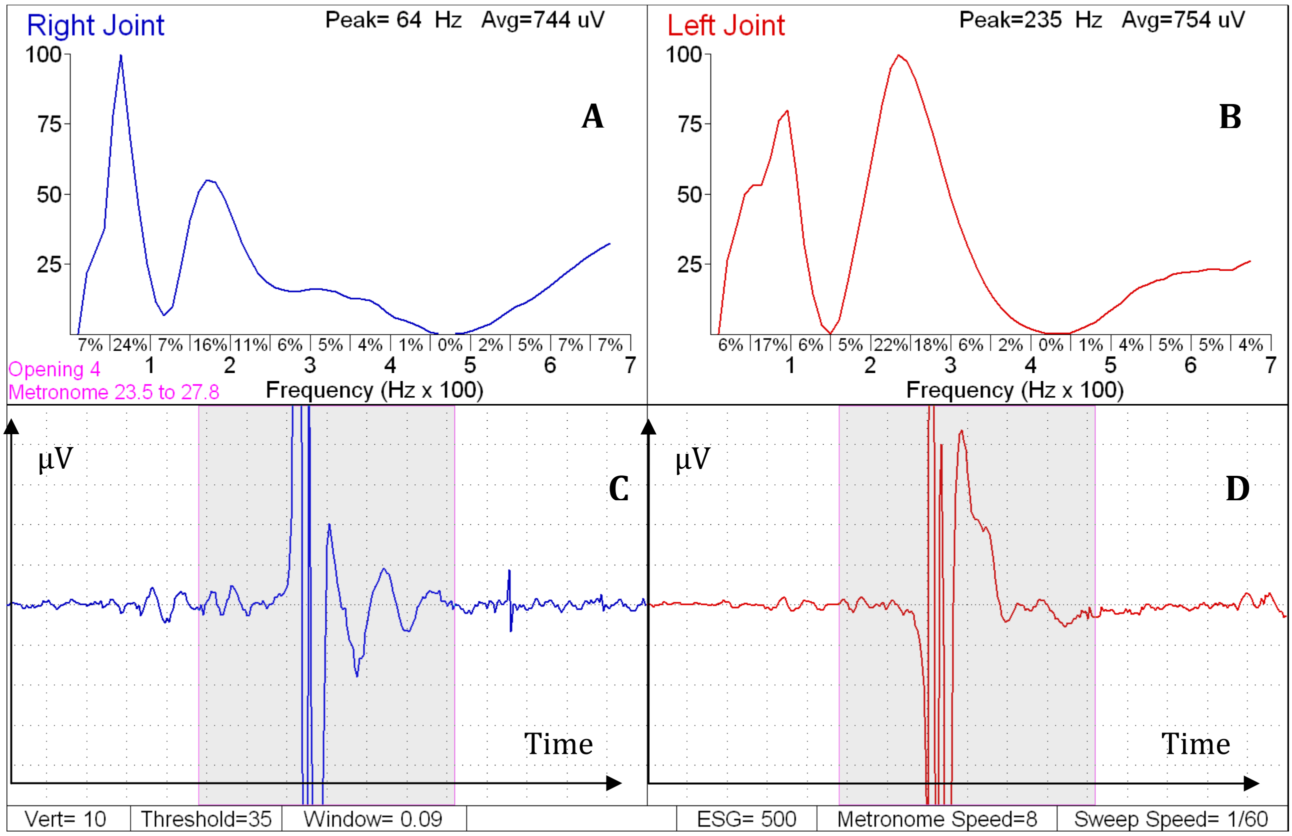

Fig 3: Spectral analysis of the peak of Fig 2:

- A Spectral analysis for the right joint indicating the frequency components of the joint sound.
- B Spectral analysis for the left joint indicating the frequency components of the joint sound.
- C Sound representation of the right joint.
- D Sound representation of the left joint.

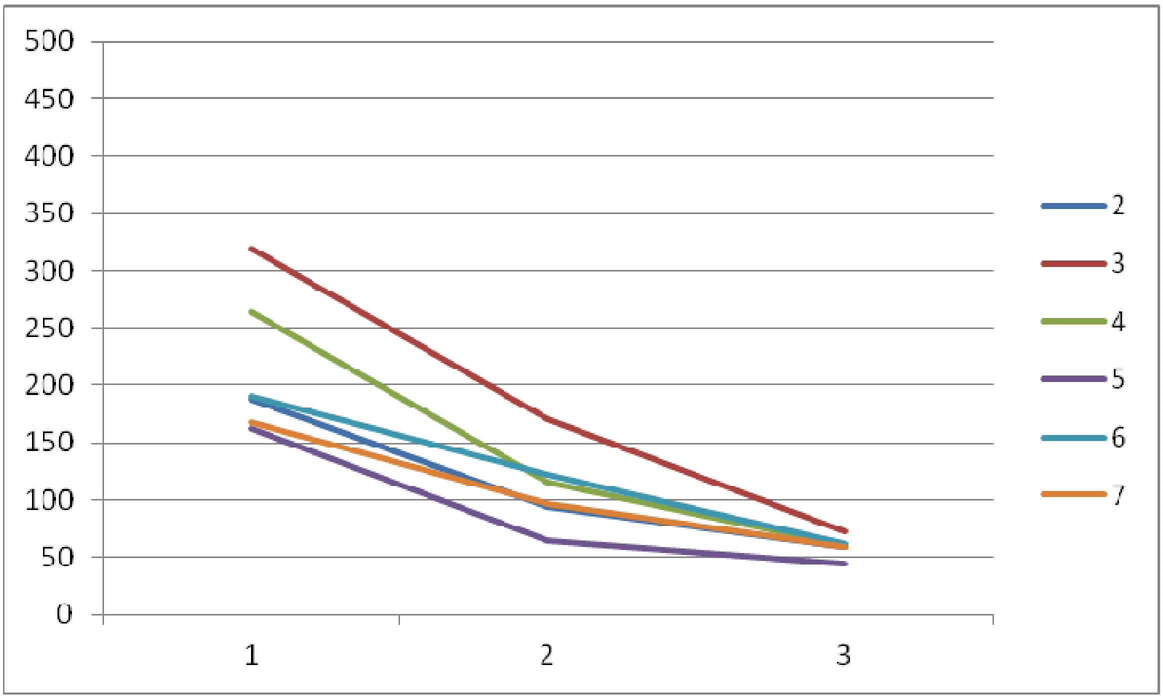

Fig 4: Mean frequency (Hz) of the sound of the ESG's peaks divided in three parts (1=first third, 2=second third, 3=last third) during the opening phase. Data are divided following the Tasaki's classes.

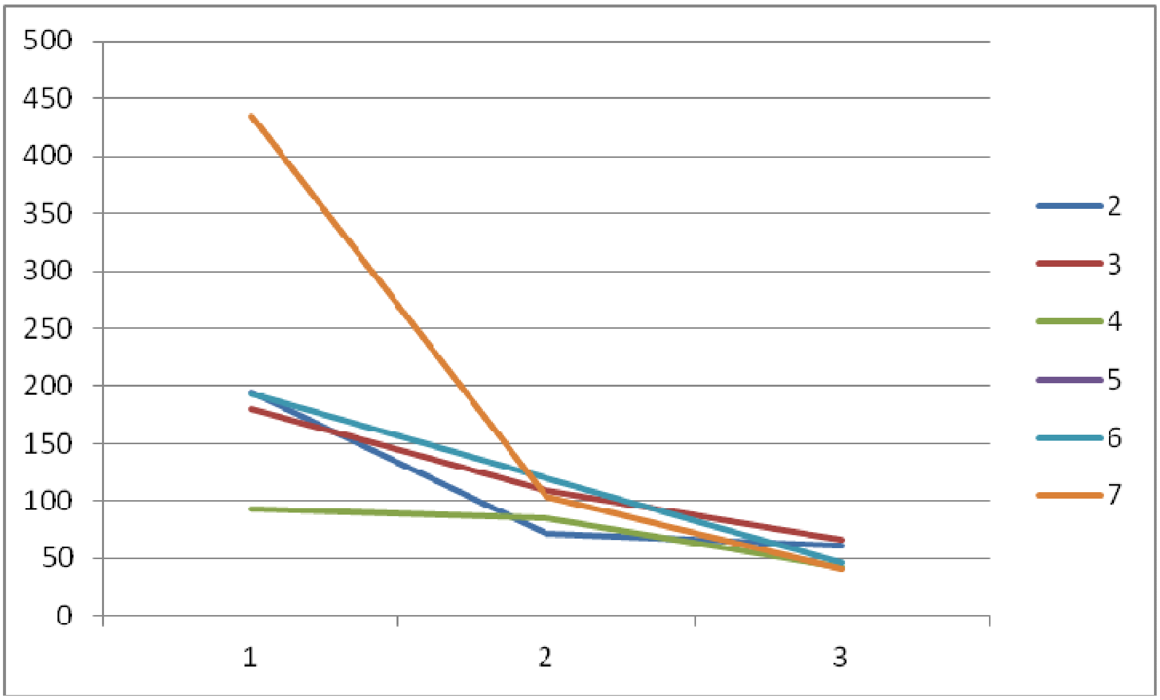

Fig 5: Mean frequency (Hz) of the sound of the ESG’s peaks divided in three parts (1=first third, 2=second third, 3=last third) during the closing phase. Data are divided following the Tasaki’s classes.

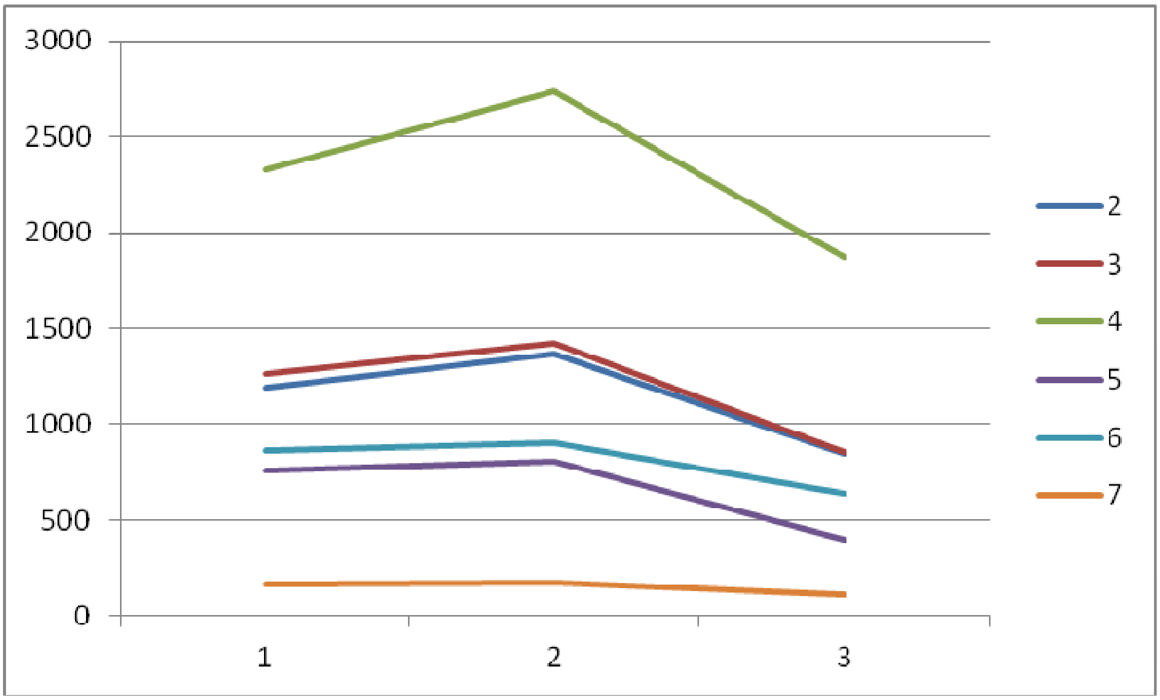

Fig 6: Mean intensity (µV) of the sound of the ESG's peaks divided in three parts (1=first third, 2=second third, 3=last third) during the opening phase. Data are divided following the Tasaki's classes.

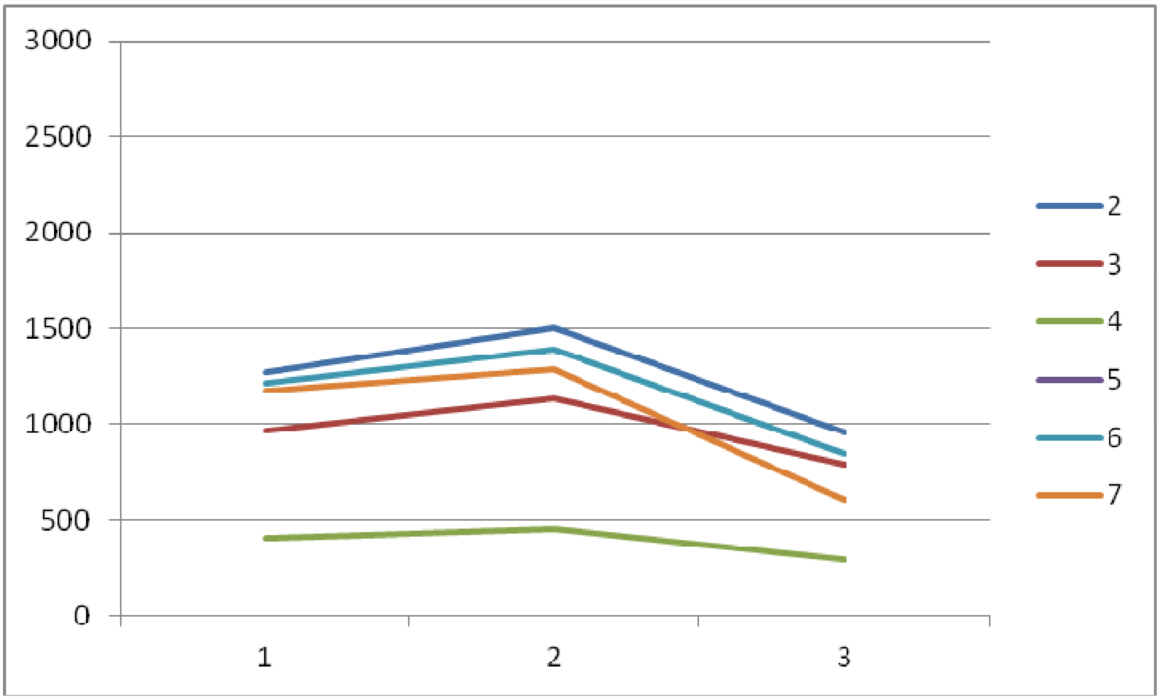

Fig 7: Mean intensity (µV) of the sound of the ESG's peaks divided in three parts (1=first third, 2=second third, 3=last third) during the closing phase. Data are divided following the Tasaki's classes.